I. INTRODUCTION

Wetlands are among America's most endangered ecosystems, with more than 50 percent of them having been lost in the lower 48 states since pre-colonial times (Dahl 1990). In California, aerial photo studies indicate that as much as 80 to 90 percent of historic habitat has been lost and that the loss continues unabated (Holland 1978, 1998). The few wetlands that remain, or that have been re-created, in the Central Valley are among the most valuable and biologically productive ecosystems in the state, fulfilling a variety of beneficial needs that include protecting and improving water quality by absorbing and storing floodwaters, filtering pollutants, and maintaining surface water flows during dry periods; providing fish and wildlife habitats; and offering recreational opportunities to millions of Americans annually. Because of their productivity, wetlands support a great diversity of plants and animals, both aquatic and terrestrial, including both federally and State listed threatened and endangered species.

Vernal pools are a unique kind of wetland ecosystem. Central to their distinctive ecology is their ephemeral nature. Vernal pools fill with water temporarily, typically during the winter and spring, and then disappear until the next rainy season. In California, where extensive areas of vernal pool habitat developed over a long geological timeframe, unique suites of plants and animals have evolved that are specially adapted to the unusual conditions of vernal pools. Fish and other predators are among species that have been excluded evolutionarily by the annual filling and drying cycles of vernal pools. The prolonged annual dry phase of the vernal pool ecosystem also has prevented the establishment of plant species typical of more permanent wetland ecosystems.

California and southern Oregon vernal pools are also renowned for their showy displays of spring wildflowers, blooming in concentric rings around the pools. Native bees pollinate these vernal pool wildflowers while crustaceans and other insects produce cysts and eggs that lie buried in the mud awaiting the next rainy season alongside seeds of plants produced in past years. In essence, vernal pools constitute a "bank" of life waiting to emerge at the onset of the next rainy season.

A. OVERVIEW

1. Species Represented

This recovery plan covers 33 plant and animal species associated with vernal pools, 20 of which are federally listed as endangered or threatened (**Table I-1**). Covered plants include 10 that are endangered, 5 that are threatened, and 10 species of special concern. Covered animals include three that are endangered, two that are threatened, and three species of special concern.

Of the 20 federally listed species included in this recovery plan, 2 have a previously approved final recovery plan. A combined recovery plan for the delta green ground beetle (*Elaphrus viridis*) and *Tuctoria mucronata* (Solano grass) was approved in 1985 (U.S. Fish and Wildlife Service 1985*a*). Thus, this recovery plan represents a revision of the final recovery plan for those species.

Thirteen plant and animal species of concern that occur within vernal pools are fully considered in this recovery plan (**Table I-1**). Species of concern are sensitive species that have not been listed, proposed for listing nor placed in candidate status. “Species of special concern” is an informal term used by some but not all of our offices. Species of concern receive no legal protection and the use of the term does not necessarily mean that the species will eventually be proposed for listing as a threatened or endangered species. One species of concern addressed in this plan, *Plagiobothrys hystriculus* (bearded popcorn flower) is presumed extinct.

Critical Habitat

Of the 20 federally listed species included in this recovery plan, critical habitat has been designated for 11 plants and 4 animals within the *Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon; Evaluation of Economic Exclusions From August 2003 Final Designation; Final Rule* (U.S. Fish and Wildlife Service 2005). Additionally, critical habitat has been designated for the delta green ground beetle (U.S. Fish and Wildlife Service 1980a).

Section 4 of the Endangered Species Act requires that we designate critical habitat on the basis of what we know at the time of designation. Habitat is often dynamic, and species may move from one area to another over time. Furthermore, we recognize that designation of critical habitat may not include all of the habitat areas that may eventually be determined to be necessary for the recovery of the species. For these reasons, critical habitat designations do not signal that habitat outside the designation is unimportant or may not be required for recovery. Some areas within Zone 1 and Zone 2 core areas were excluded from critical habitat for economic reasons (U.S. Fish and Wildlife Service 2005), creating a discrepancy between the core area boundaries and critical habitat. We anticipate that some lands in recovery core areas outside of the areas designated as critical habitat will be necessary for recovery. Additionally, this recovery plan covers a total of 33 species, 20 of which are listed under the Act. Of those listed species covered in this plan, critical habitat has been designated for 16 species. As critical habitat has not been designated for the remaining four listed species (see Table I-1), it is not possible to state whether or not the boundaries of the critical habitat designation would match those of the recovery core areas, if in fact critical habitat had been designated for those four species.

Similarly, critical habitat designations made on the basis of the best available information at the time of designation will not control the direction and substance of future plans, or other species conservation planning efforts if new information available to these planning efforts calls for a different outcome.

Critical habitat affects Federal agencies by requiring them to evaluate the effects that any activities they fund, authorize, or carry out may have on listed species. Agencies are required to ensure that such activities are not likely to jeopardize the survival of a listed species or adversely modify (*e.g.*, damage or destroy) its critical habitat. By consulting with us, Federal agencies can usually minimize or avoid any potential conflicts and, thus, activities usually proceed in some form. It should be noted that critical habitat designation does not create a wilderness area, preserve, or wildlife refuge. It applies only to activities sponsored at least in part by Federal agencies. Such federally-permitted land uses as grazing and recreation may take place if they do not adversely modify critical habitat. Designation of critical habitat does not constitute a land management plan nor does it signal any intent of the government to acquire or control the land. Therefore, if there is no Federal involvement (*e.g.*, Federal permit, funding, or license), activities of a private landowner, such as farming, grazing or constructing a home, generally are not affected by a critical habitat designation, even if the landowners' property is within the geographical boundaries of critical habitat. Without a Federal nexus to a proposed action, designation of critical habitat does not require that landowners of State or other non-Federal lands do anything more than they would otherwise do to avoid take under provisions of section 9 and 10 of the Endangered Species Act. Although core areas were developed in part using critical habitat boundaries, the two areas differ in that core areas not included in critical habitat have no legal mandate for protection under the Endangered Species Act and solely rely upon voluntary implementation. Additionally, recovery planning documents are necessarily expansive, identifying as many options and strategies that may

Table I-1. Species addressed in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon.

Scientific name	Common name(s)	Status [1]	Critical Habitat Designated?	Vernal Pool Region [2]	Recovery Priority [3]
Listed Plant Species					
Castilleja campestris ssp. *succulenta*	fleshy owl's clover	FT, SE	Yes	So. Sierra Foothills	9
Chamaesyce hooveri	Hoover's spurge	FT	Yes	NE Sac, So. Sierra Foothills, Solano-Colusa	2c
Eryngium constancei	Loch Lomond button-celery	FE, SE	No	Lake-Napa	14
Lasthenia conjugens	Contra Costa goldfields	FE	Yes	Central Coast, Lake-Napa, Livermore, Mendocino, Solano-Colusa	5c
Limnanthes floccosa ssp. *californica*	Butte County meadowfoam	FE, SE	Yes	NE Sac	2c
Navarretia leucocephala ssp. *pauciflora*	few-flowered navarretia	FE, ST	No	Lake-Napa	3
Navarretia leucocephala ssp. *plieantha*[4]	many-flowered navarretia	FE, SE	No	Lake-Napa	3
Neostapfia colusana	Colusa grass	FT, SE	Yes	Solano- Colusa, So. Sierra Foothills, San Joaquin	2c
Orcuttia inaequalis	San Joaquin Valley Orcutt grass	FT, SE	Yes	So. Sierra Foothills	8
Orcuttia pilosa	hairy Orcutt grass	FE, SE	Yes	NE Sac, So. Sierra Foothills, Solano-Colusa	2c

Scientific name	Common name(s)	Status [1]	Critical Habitat Designated?	Vernal Pool Region[2]	Recovery Priority[3]
Orcuttia tenuis	slender Orcutt grass	FT, SE	Yes	Lake-Napa, Modoc Plateau, NE Sac, NW Sac, SE Sac	8
Orcuttia viscida	Sacramento Orcutt grass	FE, SE	Yes	SE Sac	5c
Parvisedum leiocarpum	Lake County stonecrop	FE, SE	No	Lake-Napa	2c
Tuctoria greenei	Greene's tuctoria	FE, SR	Yes	Modoc Plateau, NE Sac, NW Sac, So. Sierra Foothills, Solano-Colusa	2c
Tuctoria mucronata	Solano grass; Crampton's tuctoria	FE, SE	Yes	Solano-Colusa	2
Listed Animal Species					
Branchinecta conservatio	Conservancy fairy shrimp	FE	Yes	NE Sac, NW Sac, San Joaquin, Solano-Colusa,, SE Sac, So. Sierra Foothills	8
Branchinecta longiantenna	longhorn fairy shrimp	FE	Yes	Carrizo, Livermore, San Joaquin	8
Branchinecta lynchi	vernal pool fairy shrimp	FT	Yes	Carrizo, Central Coast, Klamath Mtn.[5], Livermore, NE Sac, NW Sac, San Joaquin, Solano-Colusa, SE Sac, So. Sierra Foothills, W. Riverside	2c
Elaphrus viridis	delta green ground beetle	FT	Yes	Solano-Colusa	8

I-5

Scientific name	Common name(s)	Status [1]	Critical Habitat Designated?	Vernal Pool Region[2]	Recovery Priority[3]
Lepidurus packardi	vernal pool tadpole shrimp	FE	Yes	NE Sac, NW Sac, San Joaquin, Solano-Colusa, SE Sac, So. Sierra Foothills	2c
Plant Species of Concern					
Astragalus tener var. *ferrisiae*	Ferris' milk vetch	none	-	NE Sac, Solano-Colusa	-
Astragalus tener var. *tener*[4]	alkali milk vetch	none	-	Central Coast, Lake-Napa, Livermore, San Joaquin, Solano-Colusa	-
Atriplex persistens	vernal pool smallscale	none	-	San Joaquin, Solano-Colusa	-
Eryngium spinosepalum	spiny-sepaled button-celery	none	-	So. Sierra Foothills	-
Gratiola heterosepala	Boggs Lake hedge-hyssop	SE	-	Lake-Napa, Modoc Plateau, NE Sac, NW Sac, Solano-Colusa, SE Sac, So. Sierra Foothills	-
Juncus leiospermus var. *ahartii*	Ahart's dwarf rush	none	-	NE Sac, SE Sac	-
Legenere limosa[4]	legenere	none	-	Lake-Napa, NE Sac, NW Sac, Solano-Colusa, SE Sac, So. Sierra Foothills	-
Myosurus minimus var. *apus*	little mousetail	none	-	San Diego, San Joaquin, So. Sierra Foothills, W. Riverside	-
Navarretia myersii ssp. *deminuta*	small pincushion navarretia	none	-	Lake-Napa	-

Scientific name	Common name(s)	Status[1]	Critical Habitat Designated?	Vernal Pool Region[2]	Recovery Priority[3]
Plagiobothrys hystriculus	bearded popcorn flower	none	-	Solano-Colusa	-
Animal Species of Concern					
Branchinecta mesovallensis	midvalley fairy shrimp	none	-	San Joaquin, SE Sac, So. Sierra Foothills	-
Linderiella occidentalis[4]	California fairy shrimp; California linderiella	none	-	Central Coast, NE Sac, Santa Barbara, San Joaquin, SE Sac, So. Sierra Foothills	-
Spea hammondii	western spadefoot toad	none	-	Central Coast, NW Sac, NE Sac, SE Sac, Solano-Colusa, So. Sierra Foothills, San Joaquin, Carrizo, W. Riverside, Santa Barbara, San Diego	-

[1] Status: FE = federally endangered, FT = federally threatened, SE = State endangered, ST = State threatened, SR = State rare

[2] Vernal Pool Regions based on Keeler-Wolf (1998).

NE Sac= northeastern Sacramento Valley

SE Sac= southeastern Sacramento Valley

NW Sac= northwestern Sacramento Valley

So.= southern

W.= western

[3] Recovery Priority: See Appendix D for description of how recovery priority numbers are assigned for listed species.

[4] Species has also been reported to occur in the Santa Rosa vernal pool region described by Keeler-Wolf *et.al*. (1998); however, these populations will be covered in the Draft Santa Rosa Plains Recovery Plan (in development).

[5] Klamath Mtn. Vernal Pool Region not based on Vernal Pool Regions from Keeler-Wolf (1998).

contribute to recovery as possible. As a result, a suite of the actions identified in this recovery plan must occur to achieve recovery. However, while failure to take any particular action in this plan will not in itself preclude recovery of any of the plan's species, the specific importance of one area or action will be dependent on which other activities in the plan are occurring or are likely to occur. Generally speaking, the more activities identified in this plan that are actually achieved, the more likely it is that recovery will take place. Conversely, the fewer actions implemented or areas protected identified in this plan, the less likely it is that recovery will be achieved.

2. Classification of Vernal Pools

a. Vernal Pool Types

The variability of vernal pool types has led many researchers to try to classify these ephemeral habitats (Holland 1986; Sawyer and Keeler-Wolf 1995; Ferren *et al.* 1996; Smith and Verrill 1998). Most of these efforts have focused on classifying vernal pools based on the factors that influence variation in their physical features. Primary physical features that influence vernal pool size, depth, and soil and water chemistry include soil type, geologic formation, and landform. Landforms are physical attributes of the landscape resulting from geomorphological processes such as erosion and deposition, and include features such as alluvial terraces and basins, volcanic mudflows, and lava flows. The types and kinds of species that are found in vernal pools are largely determined by these physical factors (Holland and Griggs 1976; Zedler 1987; Eng et al. 1990; Holland and Dains 1990; Simovich 1998).

Sawyer and Keeler-Wolf (1995) classified vernal pools according to a number of physical, geographic, and biological characteristics. They identified several general vernal pool types, each of which corresponds to the nature of the impermeable layer that underlies a particular vernal pool and influenced the formation of that pool. The vernal pool types were identified as Northern Hardpan, Northern Claypan, Northern Basalt Flow, Northern Volcanic Mudflow, and Northern Ashflow vernal pools.

Northern Hardpan vernal pools are formed on alluvial terraces with silicate-cement soil layers. These pool types are on acidic soils and exhibit well-developed mima mound topography found on the eastern margins of the Central Valley. Northern Claypan vernal pools are formed on impermeable surfaces created by an accumulation of clay particles. These pool types are often found on basin and basin rim landforms and tend to occur in the central portion of the Central Valley and tend to be alkaline. Vernal pools identified as Northern Volcanic Mudflow, Northern Basalt Flow, and Northern Volcanic Ashflow are formed by an impervious bedrock layer of volcanic origin. These pool types are found on the eastern and coastal portions of the Central Valley, and tend to be small and restricted in distribution. Northern Basalt Flow vernal pools occur at greater elevations than other vernal pool types.

The vernal pools in Southern California are associated with several soil series types including but not limited to Huerheuero, Olivenhain, Placentia, Redding, and Stockpen (Bauder and McMillan 1998). These soil types and other vernal pool bearing soils and geologic formations have a nearly impermeable surface or subsurface soil layer with a flat or gently sloping topography (Service 1998). Due to local topography and geology, the pools are usually clustered into pool complexes (Bauder 1986; Holland and Jain 1988). Pools within a complex are typically separated by distances on the order of meters, and may form dense, interconnected mosaics of small pools or a more sparse scattering of larger pools. The pools within the Santa Rosa Plateau in Riverside County, California are the only known locality for the Southern Basalt Flow Vernal Pools.

Other vernal pools and pool complexes are not currently classified, but some of these pools converge on vernal lakes and others are associated with vernal alkali plains (Keeler-Wolf et al. 1998). The vernal pools in the Agate Desert in Southern Oregon are located on alluvial fans capped with a shallow layer of clay loam over cemented hardpan. Other vernal pools within the area include those formed on older basaltic andesite formations such as those found on Table Rock. Vernal pool complexes are characterized by patterned ground with mounds and vernal pools. These pools vary in size from 1 to 30 meters (3 to 100 feet) across, and attain a maximum depth of about 30 centimeters (12 inches) (Oregon Natural Heritage Program 1997). This landform is not true desert as it receives 48 centimeters (19 inches) of precipitation annually. The pools within the area support the vernal pool fairy shrimp and other listed vernal pool species such as the endangered Cook's lomatium (*Lomatium cookii*) and large-flowered woolly meadowfoam (*Limnanthes floccosa* ssp. *grandiflora*) (U.S. Fish and Wildlife Service 2002a).

b. Vernal Pool Regions

At this time, the geographic distribution of the endangered, threatened, and rare vernal pool taxa in this recovery plan can best be represented by the vernal pool regions defined in the California Department of Fish and Game, *California Vernal Pool Assessment Preliminary Report* (Keeler-Wolf *et al.* 1998). Keeler-Wolf *et al.* (1998) defined the vernal pool regions as discrete geographic regions identified largely on the basis of endemic species, with soils and geomorphology as secondary elements, although there is some overlap of these features among vernal pool regions. Overall, these vernal pool regions are representative of the range of biotic and abiotic features for the ecosystem and species covered in this recovery plan.

The California Department of Fish and Game has identified 17 distinct vernal pool regions (Keeler-Wolf *et al.* 1998). These regions include 5 in the Central Valley (Northeastern Sacramento Valley, Northwestern Sacramento Valley, San Joaquin Valley, Solano-Colusa, and Southeastern Sacramento Valley), and 12 regions occurring throughout the remainder of California (Carrizo, Central Coast, Lake-Napa, Livermore, Mendocino, Modoc Plateau, San Diego, Santa Barbara, Santa Rosa, Sierra Valley, Southern Sierra Foothills, and Western Riverside Regions). The Sierra Valley region is not included in this recovery plan as no listed species covered in this document occur there. The Santa Rosa vernal pool region was excluded from this recovery plan because the populations of listed species and species of concern in this region will be covered in the Draft Santa Rosa Plains Recovery Plan, currently in development.

The vernal pool regions described and discussed in this recovery plan correspond closely to those regions defined by the California Department of Fish and Game (Keeler-Wolf *et al.* 1998). Deviation from the boundaries of the California Department of Fish and Game vernal pool regions was necessary in certain instances where recent data from the California Natural Diversity Database (2005) and other sources suggest the inclusion of additional areas based on species occurrences, vernal pool habitat, watershed boundary data, topographic features, Holland (1998) data, and the National Hydrography Dataset. Seven vernal pool regions discussed in this recovery plan have boundaries that differ slightly from the Keeler-Wolf *et al.* (1998) vernal pool region boundaries. Modified regions include Carrizo, Central Coastal, Lake-Napa, Modoc Plateau, Northeastern Sacramento Valley, Solano-Colusa, and Santa Barbara. Specific modifications are described in the discussion of individual vernal pool regions in the Recovery Chapter. Since the Keeler-Wolf *et al.* (1998) vernal pool regions did not include Oregon, one vernal pool region (Klamath Mountains) has been defined for species occurring in that state based on species occurrence data and watershed boundaries.

The species addressed in this recovery plan inhabit 15 of the original 17 vernal pool regions defined by the California Department of Fish and Game (Keeler-Wolf *et al.* 1998) (**Figure I-I**), as well as the Klamath Mountains Vernal Pool Region in Oregon.

3. Factors in the Development of Vernal Pools

The three most important physical factors in the development of vernal pools are climate, soil, and topography. The climate in California and southern Oregon, classified as Mediterranean due to its rainy winters and dry summers, results in the filling and drying of pools during the wet and dry seasons, respectively. Vernal pools form where precipitation and surface runoff become trapped or "perched" above an impermeable or nearly impermeable layer of soil (Smith and Verrill 1998). As previously discussed, Sawyer and Keeler-Wolf (1995) classified

California vernal pools as Northern Hardpan, Northern Claypan, Northern Basalt Flow, Northern Volcanic Mudflow, and Northern Volcanic Ashflow based on the various types of impermeable layers.

A second major factor in the development of vernal pools is soil. Vernal pools form where a soil layer exists below or at the surface that is impermeable or nearly impermeable to water (Smith and Verrill 1998). The northern hardpan layers are formed on alluvial terraces by leaching, redeposition, and cementing of silica minerals from high in the soil profile to a lower ("B") horizon (Smith and Verrill 1998). Northern hardpan vernal pools are on acidic soils and exhibit well-developed rounded soil mounds referred to as mima mound topography, found on the eastern margins of the Central Valley. Northern claypan layers are formed by a similar redeposition process of fine clay particles sometimes augmented by saline or alkaline compounds, being transported to the B horizon where they accumulate and eventually hold water. Northern claypan vernal pools are often found on basin and basin rim landforms and tend to occur in the central portion of the Central Valley. Vernal pools identified as Northern Basalt Flow, Northern Volcanic Mudflow, and Northern Volcanic Ashflow are underlain by an impervious bedrock layer of volcanic origin. These pool types are found on the eastern and coastal portions of the Central Valley, and tend to be small and restricted in distribution. Northern Basalt Flow vernal pools occur at greater elevations than other vernal pool types. Smith and Verrill (1998) list many of the soil series associated with vernal pools in the Central Valley.

The third factor in the development of vernal pools is topography. Landforms, physical attributes of the landscape resulting from geomorphological processes such as erosion and deposition, influence the development of vernal pools. Landforms include such features as alluvial terraces and basin rims, and volcanic mudflows and lava flows. Vernal pools typically occur in landscapes that, at a broad scale, are shallowly sloping or nearly level, but on a fine scale may exhibit extreme topography. From the air, vernal pool landscapes often show characteristic patterning, produced by plant responses to mound and trough micro-relief, and such patterning has allowed detailed mapping of vernal pool habitats throughout California's Central Valley and adjacent areas (Holland 1998).

4. Physical Characteristics of Vernal Pools

Vernal pools vary from 1 square meter (approximately 1 square yard) to 1 hectare (2.5 acres) or more. Some larger vernal features, such as the 36-hectare (90-acre) Olcott Lake in the Jepson Prairie Preserve in Solano County, are also referred to as vernal lakes, playa pools, or lakes. Playa pools or lakes with high alkalinity are termed alkali sinks. These larger features share much of the flora and fauna of smaller pools, including many rare and endangered species included in this recovery plan.

Vernal Pool Regions

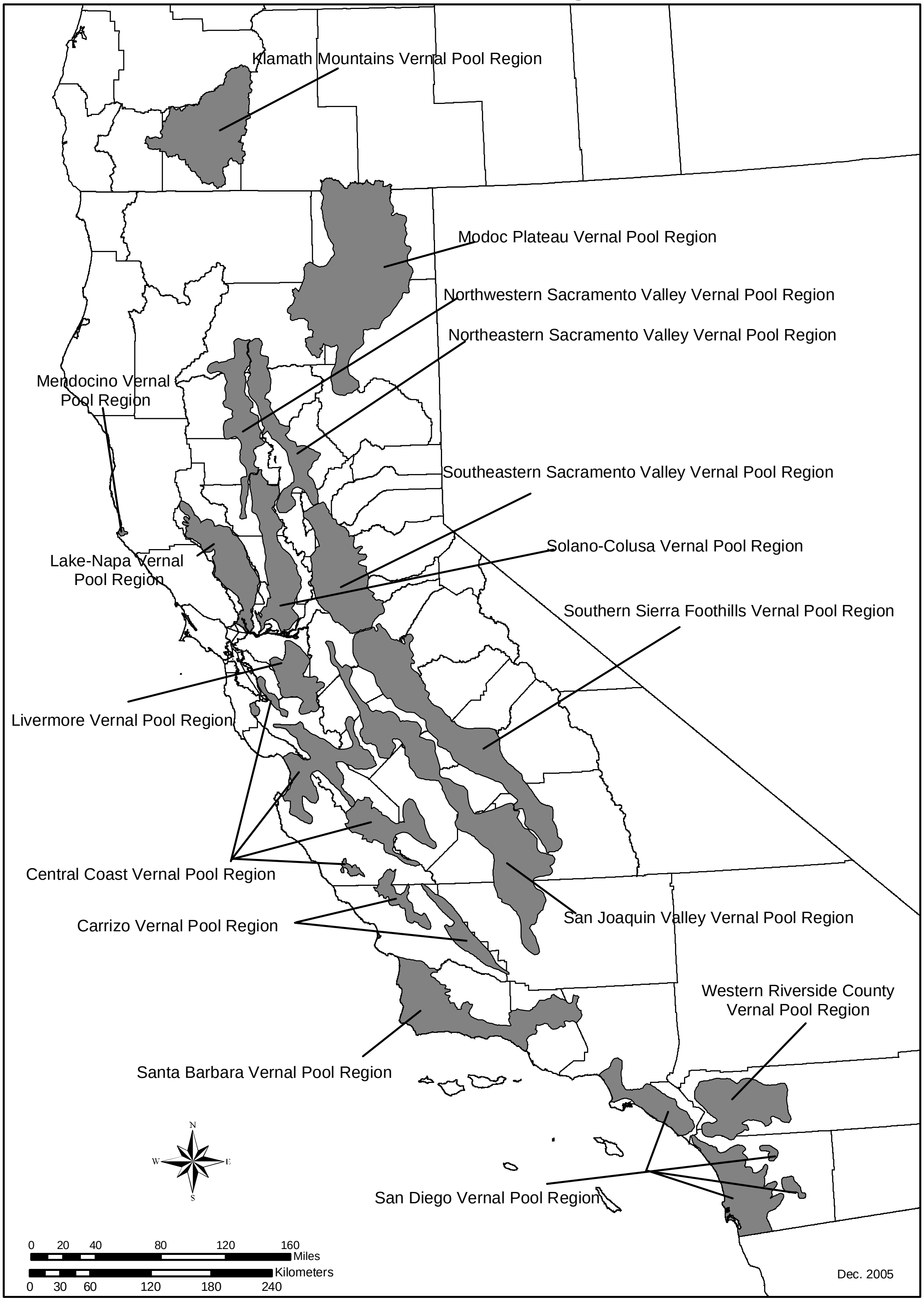

Figure I-1. Map of recovery plan area showing location of vernal pool regions.

Vernal pools in California tend to occur in clusters, called “complexes”, because appropriate combinations of climate, soil, and topography often occur over continuous areas rather than in isolated spots. Landscapes that support vernal pool complexes are typically grasslands with areas of obstructed drainage that form the pools. However, vernal pools also can be found in a variety of other habitats, including oak woodland, desert, and chaparral. The pools may be fed or connected by low drainage pathways called “swales.” Swales often remain saturated for much of the wet season, but are not inundated long enough to develop strong vernal pool characteristics. Trees are relatively rare in vernal pool complexes because of their shallow, seasonally saturated or inundated and sometimes alkaline soils, and their characteristic root-restricting subsurface layer. For the same reasons, vernal pool complexes have historically been considered poor farmland.

California’s vernal pools begin to fill with the winter rains. Before ponding occurs, there is a period during which the soil is wetted and the local water table may rise. Some pools are primarily fed by the surrounding watershed; others may fill almost entirely from rain falling directly into the pool (Hanes and Stromberg 1998). Although exceptions are not uncommon, the watershed generally contributes more to the filling of larger or deeper pools, especially playa pools. Even in pools filled primarily by direct precipitation, Hanes and Stromberg (1998) report that subsurface inflows from surrounding soils can help to damp water level fluctuations during late winter and early spring.

Both the amount and timing of winter and spring rainfall in California vary greatly from year to year. For this reason and others, pools may fill to different extents at different times. The duration of ponding of vernal pools also varies, and in some years certain pools may not fill at all. A recent study found evidence of droughts in California, as recently as medieval times, that far exceeded in duration and severity anything experienced since the arrival of Europeans (Stine 1994). Many characteristics of vernal pool plants and animals are dynamic adaptations to the highly variable and unpredictable nature of vernal pool environments.

The chemical characteristics of California vernal pools are diverse. The pH has been observed to vary between 6 and 10 in a southern California vernal pool (Keeley and Zedler 1998). Dissolved carbon dioxide can approach zero. Such conditions may limit photosynthetic production in the pools (Keeley 1990). Seasonal variation also is a factor in the diversity of vernal pool water chemistry (Helm 1998).

5. Vernal Pool Communities

The physical characteristics of vernal pools, as described above, influence the type of species found and their life history characteristics, such as the speed with which a species can mature and reproduce, the amount of soil moisture required for germination of plant seeds or hatching of invertebrate eggs or cysts, as well as tolerance to turbidity, total dissolved solids, and other aspects of vernal pool water chemistry (Holland and Griggs 1976, Zedler 1987, Eng *et al.* 1990, Holland and Dains 1990, Simovich 1998).

Many California vernal pool species are endemic, or found nowhere else in the world. In addition, while most of California's grasslands are now dominated by nonnative grasses and other introduced plants, accounting for a third of the species and more than 90 percent of the biomass in a California grassland, many vernal pools remain dominated primarily by native species. Seventy-five to 95 percent of plant species found in most undegraded vernal pools are native, and natives dominate in biomass as well as in number (Holland and Jain 1988, Jokerst 1990, Spencer and Rieseberg 1998). Vernal pool communities dominated by natives persist even while surrounded by grassland composed of nonnative vegetation. Vernal pool plant communities are able to resist invasion of nonnative plants in the portion of the pool that experiences prolonged inundation, where plants are severely constrained by environmental conditions with which nonnative plants have not evolved. However, when exotic grasses in the uplands are ungrazed for several years, vernal pool margin and swale natives experience microhabitat conversion due primarily to shading from the build-up of thatch. The grass thatch inhibits the germination of native annuals, but has little if any retarding effect on the germination and growth of exotic grasses. Results from an on-going California Department of Fish and Game study show that thatch depth is negatively correlated with frequency and percent cover of native forb species (M. McCrary, pers. comm. 2004).

Plants. Almost all California vernal pool plants are annuals, which means they grow, set seed, and die in a single growing season. The annual life cycle is an adaptation to the short growth period during the pool's drying phase and to extreme year-to-year variation in rainfall (Stone 1990, Zedler 1990). Many vernal pool plants germinate during the wetting phase or under water. Among some plants that can grow under water, many show underwater morphology distinct from parts of the same plant growing above water.

Many vernal pool plants exhibit unique adaptations to limit seed dispersal, as their seeds are unlikely to succeed in adjacent upland areas. Commonly, fruits and seeds are simply retained in the dried inflorescence (flowers). Some flowers are below the soil surface, with long styles (female organs) that reach above ground for fertilization, while the fruits and seeds remain below ground. In others, the peduncles (stems supporting the flowers and fruits) lengthen and push the fruit and seeds into the soil (Zedler 1990).

One of the most dramatic adaptations of vernal pool plants to their unique environment is their ability to remain dormant as a seed for years or even decades. While dormant, these tiny propagules must resist extreme heat and drought, repeated wetting and drying, and be able to re-activate their metabolism and life cycle when conditions are appropriate. The cues they use to emerge from dormancy are poorly understood. Studies and models of other seed banks in highly variable environments suggest that dormancy is a strategy to spread offspring across many years. In this way, not all seeds are lost in a climatically unfavorable year and at least some encounter more favorable conditions in future years.

Animals. Vernal pool animal communities also contain unique species. The most visible crustaceans in vernal pools are the large branchiopods (literally, “gill-foots”), comprising about 25 species in California of which approximately 8 species are endemic (King *et al*. 1996, Eriksen and Belk 1999) and 6 are federally listed as threatened or endangered. The federally-listed vernal pool shrimp found in southern California, Riverside fairy shrimp (*Streptocephalus woottoni*) and San Diego fairy shrimp (*Branchinecta sandiegonensis*), are covered in the Vernal Pools of Southern California Recovery Plan (U.S. Fish and Wildlife Service 1998a).

These branchiopod crustaceans all have life cycles adapted to the ephemeral and variable nature of vernal pools. Many are capable of producing cysts or eggs that can tolerate extreme and prolonged drying and high temperatures. Like the seeds of vernal pool plants, the cysts lie dormant in the soil, sometimes for many years (Belk 1998), until some poorly understood combination of environmental cues or an internal clock trigger them to hatch and begin the life cycle again. Some vernal pool crustacean species undergo more than one generation in a single wet season. Often eggs produced early in the season are of a different form, adapted to rapid development and hatching, and incapable of entering a resistant phase. Eggs produced later in the season may have the ability to lie dormant, if necessary. Species may reproduce sexually and/or parthenogenetically (when females reproduce clonally).

Amphibians and many insect species also live in vernal pools and the surrounding upland habitat, including two rarer amphibians native to vernal pools, the California tiger salamander (*Ambystoma californiense*) and the western spadefoot toad (*Spea hammondii*) (Morey 1998). The California tiger salamander, which co-occurs with some of the species in this plan, will be covered in the Draft Santa

Rosa Plains Recovery Plan (in development), and in the Draft Central Valley California Tiger Salamander Recovery Plan (to be developed).

The insect fauna of vernal pools is numerous, varied, and primarily native, including aquatic beetles (Coleoptera: Dytiscidae, Hydrophilidae, Gyrinidae, Halipidae, Hydraenidae), aquatic bugs, including backswimmers (Hemiptera: Notonectidae), water boatmen (Corixidae), and water striders (Gerridae), springtails (Collembola), mayflies (Ephemeroptera), dragonflies and damselflies (Odonata), and various flies with aquatic larvae, including midges (Diptera: Chironomidae), crane flies (Tipulidae) and mosquitoes (Culicidae), to name a few.

The plants and animals of vernal pools are important providers of food and habitat for waterfowl, shorebirds, and other species (Silveira 1998). Vernal pool complexes contribute to the continuity of wetland habitats along the Pacific Flyway. Ducks feed on vernal pool crustaceans and other invertebrates, which are sources of protein and calcium needed for migration and egg production. Cliff swallows (*Petrochelidon pyrrhonota*) glean mud from vernal pool beds for their nests, lesser nighthawks (*Chordeiles acutipennis*) nest in dry vernal pool beds, burrowing owl (*Athene cunicularia*) and pocket gopher (*Thomomys* spp.) burrows are found in mima mounds, and many species graze or hunt along vernal pool shorelines. Before their populations declined, elk (*Cervus elaphus*) and pronghorn antelope (*Antilocapra americana*) undoubtedly grazed vernal pool landscapes. Today, most grazing on vernal pools is done by domestic ungulates.

Certain species appearing to live outside the vernal pool community are nonetheless essential to it. For example, many vernal pool plants rely on insect pollinators, which do not reside in the pools themselves. Many native pollinators of vernal pool plants are solitary bees that make their individual nests in holes in the ground of the grasslands surrounding the pools (Thorp and Leong 1998). California ground squirrel (*Spermophilus beecheyi*) burrows provide summer refuges for adult and juvenile California tiger salamanders. Upland plant communities around vernal pools regulate runoff, remove nutrients, and filter out sediment. Grazers may have important and sometimes complex effects on vernal pool plant communities, as well as on thatch accumulation, nutrient levels, and physical disturbance.

6. Major Threats to Vernal Pool Species

Habitat loss and fragmentation is the largest threat to the survival and recovery of the listed species and species of concern addressed in this recovery plan. Habitat loss generally is a result of urbanization, agricultural conversion, and mining. Habitat loss also occurs in the form of habitat alteration and degradation as a result of changes to natural hydrology; invasive species; incompatible grazing regimes, including insufficient grazing for prolonged periods; infrastructure projects (*e.g*., roads, water storage and conveyance, utilities); recreational activities (*e.g.*, off-highway vehicles and hiking); erosion; climatic and environmental change; and contamination.

Habitat fragmentation generally is a result of activities associated with habitat loss (*e.g.*, roads and other infrastructure projects that contribute to the isolation and fragmentation of vernal pool habitats). The loss, fragmentation and isolation of functional vernal pool ecosystems has threatened the continued existence of the listed species and species of concern addressed in this recovery plan. Most species addressed in this recovery plan are threatened by similar factors because they occupy the same vernal pool ecosystems. These threats are discussed in greater detail below.

Historic habitat loss and fragmentation. Beginning around the mid-1800's, the primary threat to vernal pools was conversion to agriculture and water conveyance and storage projects (Frayer *et al.* 1989, Kreissman 1991). Holland (1998) estimated that almost three-quarters of vernal pool habitats in the Central Valley of California had been lost by 1997. Suitable habitat for vernal pool species occurring in the Central Valley has declined dramatically over the past century, and pressure to develop remaining lands in the Central Valley is increasing rapidly. Loss of habitat has been even more extensive in areas outside of the Central Valley. Along the Central California coast, at least 90 percent of historic vernal pools have been destroyed, and most remaining vernal pools have been degraded (Ferren and Pritchett 1988). In southern California, estimated loss of vernal pool habitat ranges from 95 to nearly 100 percent (Bauder 1987, Oberbauer 1990, Zedler 1990, Bauder and McMillan 1998). In the Agate Desert area of Oregon, 60 percent of vernal pool habitats have been destroyed, and only 18 percent of the remaining habitats are considered intact (Oregon Natural Heritage Program 1997; Borgias and Patterson 1999).

Current habitat loss and fragmentation. California has both the highest absolute and fastest relative human population growth in the United States. California's population is predicted to grow by almost 18 million by the year 2025, an increase of over 50 percent, the highest of any state in the nation (U.S. Census Bureau 1996). Approximately 73 percent of the land within the Central Valley is privately owned, and in areas containing vernal pool habitats, only 6 percent of the land area is in public ownership (California Department of Fish and Game 1998). According to the 1997 National Resources Inventory (U.S. Department of Agriculture 2000), California ranked sixth in the nation in amount of non-Federal land developed between 1992 and 1997, at over 221,200 hectares

(546,700 acres). This predicted population growth will continue to threaten vernal pool habitats, most of which are located on private land.

Conversion of vernal pool habitats to intensive agricultural uses continues to contribute to the decline of vernal pools. From 1992 to 1998, 50,825 hectares (125,591 acres) of grazing land were converted to other agricultural uses in the Central Valley of California. It is likely that much of this land supported vernal pools. Holland estimated that more than 12,950 hectares (32,000 acres) of vernal pool habitats had been lost in the San Joaquin Valley vernal pool region from the late 1980's until 1997, mostly as a result of agricultural conversion. Through section 7 of the Endangered Species Act, our Sacramento Fish and Wildlife Office has reviewed projects converting more than 6,070 hectares (15,000 acres) of vernal pool habitats to intensive agricultural uses since 1994.

In more recent years, vernal pool habitats have been lost primarily as a result of widespread urbanization. Since 1994, the Sacramento Fish and Wildlife Office has conducted section 7 consultation on impacts to almost 20,250 hectares (50,000 acres) of vernal pool habitats across California. Over half of this loss of habitat, 10,125 hectares (25,000 acres), was the result of residential, commercial, and industrial development projects. The construction of infrastructure associated with urbanization also has contributed greatly to the loss and fragmentation of vernal pool plant and crustacean populations, including the construction of highways, wastewater treatment plants, sewer lines, water supply projects, and other utility projects. Some of these impacts to vernal pool habitat have been offset, in part, by compensation which includes the preservation and long-term management of vernal pool habitat for the benefit of the listed species as terms and conditions of section 7 consultations.

Mining activities, particularly gravel and clay mining needed to support development of roads and other urban infrastructure, has destroyed vernal pools and degraded surrounding vernal pool complexes in many areas. It is currently unknown how much habitat loss is attributable to mining activities.

Effects of habitat fragmentation, alteration, and degradation. Direct losses of habitat, as discussed above, generally represent irreversible damage to vernal pools. Alteration and destruction of the habitat as a result of urbanization, agriculture, and mining often disrupts the physical processes conducive to functional vernal pool ecosystems. The more severe the alteration and destruction, the more difficult it is to recover such areas in the future due to disruption of soil formations, hydrology, seed banks, and other components of a functional vernal pool ecosystem.

Agricultural conversion and urbanization, as well as the construction of infrastructure including the construction of new highways, wastewater treatment plants, sewer lines, water supply projects, wind energy development projects, and other utility projects, have also contributed greatly to the destruction and fragmentation of vernal pool habitat. Habitat loss exacerbates the highly fragmented distribution of many of the listed species and species of concern addressed in this recovery plan, increases the vulnerability of adjacent populations of such species to random environmental events, and further disrupts gene flow patterns between populations of such species. Habitat fragmentation, alteration, and degradation may effectively serve as a barrier to dispersal for some species and may bisect the range of such species locally. Although genetic evidence suggests movement between historically disjunct vernal pool complexes was probably low (Hebert 1974, Havel *et al.* 1990, Boileau and Hebert 1991, Fugate 1992, King 1996, Davies *et al.* 1997), current fragmentation of originally intact vernal pool complexes could contribute significantly to the loss of genetic diversity among vernal pool plants and crustaceans, and reduce the likelihood of recolonization events following local population extinctions (Fugate 1998). Some additional effects of fragmentation on vernal pool crustaceans may be indirect, through their effect on an associated species. For example, the fragmentation of vernal pool habitats may decrease habitat suitability for avian species, resulting in decreased use of the smaller, isolated patches, especially those adjacent to incompatible land uses (J. Silveira, pers. comm. 2004). Such an effect on birds can have consequences on the genetic stability of populations of listed branchiopods because avian species are dispersal agents for the vernal pool crustaceans (Proctor 1964, Krapu 1974, Swanson *et al.* 1974, Driver 1981, Ahl 1991).

No information exists regarding the minimum area of land (wetlands and uplands) needed to sustain viable populations of the listed species or species of concern addressed in this recovery plan. Generally speaking, as populations become isolated and/or smaller such patches have a higher propensity towards localized extinction events. Effective management regimes also become difficult and expensive to implement on isolated and/or small patches. Limiting the size of a preserved area or preserving an area geographically isolated from other preserves could preclude the long-term conservation of the species. To alleviate threats from isolated or small populations, measures must be taken to ensure functions and processes occur that favor sustainable populations and associations of listed species and species of concern covered by this recovery plan, including pollinators for plants. Minor fragmentation of vernal pool habitats may effectively serve as a seed, pollen, and pollinator dispersal barrier between adjacent sites for many of the plants covered by this recovery plan. Habitat fragmentation will also lead to reduced gene flow between populations and a potential for loss of genetic variation within populations and greater susceptibility to disease and mortality due to stochastic events (G. Platenkamp *in litt*. 2005).

<u>Altered hydrology</u>. In addition to direct habitat loss, vernal pool crustacean and plant populations have declined because of a variety of activities that render existing vernal pools unsuitable for the species. Vernal pool hydrology can be altered directly when swale systems connected to vernal pools are dammed by physical barriers, such as roads and canals. These barriers can alter vernal pool hydrology both upstream and downstream of the barrier by truncating connectivity and flow. Vernal pool hydrology also may be altered by changes to patterns of surface and subsurface flow, depending on topography, precipitation, and soil types (Hanes *et al*. 1990, Hanes and Stromberg 1998). The increased runoff and nuisance flows associated with urban development and impervious surfaces may result in altered hydrology of seasonal wetlands on and off-site. For example, stormwater drains, or the coverage of land surfaces with concrete, asphalt, or irrigated lawns, can alter the duration, volume discharge and frequency of surface flows through increased flooding and runoff.

Vernal pool hydrology also may be altered by excluding livestock and/or changing the grazing intensity and/or season of use. Grazing animals may help to maintain appropriate inundation periods by limiting vegetation accumulation and by sustaining soil conditions that create favorable vernal pool habitat (Barry 1995). A significant amount of vegetation can grow around the edges of vernal pools on sites excluded from grazing. Standing dry or dead vegetation may reduce runoff by increasing net rain loss due to interception and direct evaporation. Accumulation of dry matter around a vernal pool can affect the length of inundation, especially in a low rainfall year (Barry 1998). The removal of cattle grazing from historically grazed grasslands has been found to dramatically decrease the inundation period of vernal pools (Marty 2004). The changes in vernal pool hydrology that occur from livestock exclusion are interrelated with the invasion of nonnative annual species. The percentage of nonnative vegetation in a vernal pool is closely tied to length of inundation (Bauder 1987).

The timing, frequency, and duration of inundation are critical to the survival of vernal pool species. Alterations of the hydrology can be particularly harmful to vernal pool crustaceans and the western spadefoot toad due to premature pool dry-down before the life cycles of the species are completed, preventing reproduction and disrupting gene flow. Flowing water that artificially removes plants and animals, including cysts, eggs or seeds, from the vernal pool complex also can prevent successful reproduction and disrupt gene flow. Water flow into vernal pools during the summer can significantly alter vernal pool species composition (Clark *et al.* 1998). Longer periods of inundation and/or changes in water depth could effectively change seasonal wetland functions (*e.g.*, change from vernal pool to perennial/permanent wetlands) and floral composition (*e.g.*, community changes from annual herbs to emergent macrophytes), which in turn may lead to the extirpation of some vernal pool plants. Longer periods of inundation may result in damage to the seed bank by facilitating seed rot, triggering unseasonable germination, or other effects. With respect to animals, a more permanent aquatic community may provide suitable habitat for introduced bullfrogs (*Rana catesbeiana*) and fish. These species are significant predators of vernal pool fairy shrimp and other vernal pool crustaceans (Bauder 1987).

Other causes of altered hydrology include impoundments such as reservoirs, stockponds, and other more permanent pools, which may decrease the period of inundation of a vernal pool complex. The construction of water conveyance systems (*e.g*., canals) for irrigation, flood control, and other purposes through vernal pool habitats can dewater vernal pools via conduction of surface and subsurface flows into the canal. In addition to these causes of dewatering, encroachment of exotic grasses and the build-up of a thatch layer on pool margins and throughout vernal swales is an additional factor that decreases the hydroperiod (Marty 2004).

Runoff from irrigated agricultural lands also can alter the hydrology of adjacent vernal pools and also can contribute to erosion, siltation, and contaminant loads. In some areas, the alteration of hydrology, often in combination with specific land use practices, has caused downcutting of sloughs and swales, thus threatening the stability and functions of adjacent vernal pools. Any ground-disturbing activities, such as plowing, trenching, grading, deep-ripping, scraping, off-road vehicles, inappropriate management of livestock grazing, or other activities, adjacent to or within the watersheds of vernal pools can result in siltation when pools fill during the following wet season. Siltation is particularly likely in areas where high, disturbed slopes rise above the level of the vernal pools. Poorly designed trail and road systems near vernal pools may also cause erosion and result in siltation of vernal pools. Vernal pool crustaceans and larval amphibians may suffocate in pools with high degrees of siltation and turbidity due to their respiration through gills or gill-like organs. Siltation also may result in the burial and/or asphyxiation of eggs and cysts. Similarly, plants may not be able to germinate if too much siltation occurs.

Invasive Species. Although not all non-native species are harmful, those that outcompete native species or alter functioning of established ecosystems are usually considered invasive and undesirable. When invasive, nonnative species enter an ecosystem they can disrupt the natural balance resulting in reduction of biodiversity, degradation of habitats, alteration of native genetic diversity, and further threats to already endangered plants and animals (U.S. Environmental

Protection Agency 2005). The introduction of invasive species occurs through a variety of methods such as escape of plants used for ornamental gardening, agriculture, or erosion control, and dispersal via wind, water, animals, motor vehicles, cargo containers and dumping of ship ballasts.

Vernal pool plant species have declined due to the introduction of invasive, nonnative plant and animal species. Several factors contribute to the decline, including competition with invading plant species for nutrients, light, and water. Disturbance regimes that are not natural to the area may support invasive species distribution. Such disturbance includes urbanization, agricultural activities (Hannah *et al.* 1994 as cited in Stylinski and Allen 1999), as well as altered fire and grazing frequency (Stylinski and Allen 1999). The western states, California in particular, have been subject to these disturbances including aggregate mining and deep-ripping of the soil for vineyard development, which open the way for many exotic species to become established and reduce the species diversity within an area.

Invasive species are considered to be a threat to many of the vernal pool species covered by this plan. For example, two invasive species, *Lepidium latifolium* (perennial pepperweed) and *Crypsis schoenoides* (swamp grass), have invaded vernal pool habitat formerly occupied by *Tuctoria mucronata* and *Astragalus tener* var. *tener*, species that are addressed in this plan. These invasive plants have become a catalyst for an eradication plan in the Sacramento Valley region (Niall McCarten, Environmental Science Associates, CALFED report, August 2005).

Mosquitofish (*Gambusia affinis*), a small fish native to southeastern United States, are commonly stocked in permanent or temporary waters for mosquito control. Leyse *et al.* (2004) found that mosquitofish frequently prefer the California fairy shrimp (*Linderiella occidentalis*), one of the species addressed in this plan, to alternative prey including mosquito larvae. The listed fairy shrimp in this plan are similar in size to the California fairy shrimp, and occupy vernal pool habitat that may be stocked by mosquitofish. Therefore, mosquitofish may be a threat to the fairy shrimp species in this plan.

Contaminants. Vernal pool plant and crustacean populations also have declined as a result of water contamination. Vernal pool crustaceans are highly sensitive to the chemistry of their vernal pool habitats (Belk 1977, Eng *et al.* 1990, Gonzalez *et al.* 1996). Use of herbicides, fertilizers, and other chemicals are common in urban and agricultural settings. Although there is a general lack of specific studies to assess effects of herbicides, fertilizers, and other chemicals on vernal pool species, such chemicals could have detrimental impacts on these species if such chemicals reach seasonal wetlands via storm or nuisance sheet flow.

Specifically, herbicides may completely inhibit growth of listed plant species and plant species of concern. Contamination of vernal pools from adjacent areas may injure or kill vernal pool crustaceans and plants either directly or indirectly via pathways including the alteration of chemical properties of a pool (*e.g.*, pH) and inhibiting and/or disrupting biochemical processes creating less suitable conditions for reproduction or germination and growth. Toxic chemicals, such as petroleum products, pesticides, herbicides, fertilizers and detergents, may wash into vernal pools during the course of activities on adjacent areas. Certain chemicals are not registered to be used in or near aquatic settings due to their toxicities to aquatic organisms. Use of such chemicals in nearby areas may result in drift or runoff into vernal pools. The specific effects of such contamination are difficult to ascertain unless an accurate assessment can be made regarding the assimilation rate, or rate of decay, of such chemicals in route to the vernal pool. Vernal pools adjacent to existing developments may be contaminated from roadway contaminants in surface runoff (*e.g.*, grease, oil, and heavy metals). Pesticides used for mosquito abatement may also kill or injure fairy shrimp. Methoprene, a growth hormone contained in the pesticide Altocid, can result in delay of development of adult shrimp which may reduce the number of resting eggs (cysts) that are formed before the pools dry (Lawrenz 1984). Pesticide applications for combating West Nile virus, a disease transmitted by infected mosquitoes, may also affect fairy shrimp. In 2005, the Sacramento/Yolo Mosquito and Vector Control District conducted pesticide spraying (ground and aerial) throughout portions of Sacramento County to control and reduce the mosquito population. The ingredients in the pesticide included pyrethrins and piperonyl butoxide, which have high toxicity to fish, should not be applied directly to water, and may affect adjacent aquatic sites through drift. It is possible that this spraying may have had adverse effects on vernal pool species.

Contamination also may result from increased discharge of contaminants such as fertilizers, herbicides, and pesticides into surface waters from golf courses, irrigated agricultural lands, or landscaped residential areas (Petrovich 1990). Fertilizer contamination can lead to the eutrophication of vernal pools, which can kill vernal pool crustaceans by reducing the concentration of dissolved oxygen (Rogers 1998). Fertilizers may benefit the growth of invasive plants and could effectively lead to localized extirpation of listed plant and animal species and species of concern addressed in this recovery plan resulting from *competition*, thatch buildup, and effects of eutrophication.

Human waste, recreational use, and vandalism. As vernal pool habitats become increasingly rare and urban development expands, threats from disposal of waste, off-road vehicle use, and vandalism increase. People often dump unwanted items such as trash, tires, and appliances in vernal pool areas. Not only can these items release toxic substances into the environment and contaminate water and soil (Ripley *et al.* 2004), but they can directly affect species by crushing them (Hathaway *et al.* 1996) and restricting photosynthesis in plants by shielding the sun. Waste material also may disrupt the natural hydrologic flow.

Certain recreational activities threaten vernal pool ecosystems. Many of the vernal pool species in this recovery plan, particularly plants, are adversely affected by off-road vehicle use, hiking, and bicycling. When off-road vehicles and bicycles cut through vernal pool complexes, they may impair hydrological functions by displacing soil causing erosion or truncating swale connectivity, thus resulting in hydrological changes. Similarly, some off-road enthusiasts, bicyclists, *etc.* may create dirt jump ramps, which also could result in the aforementioned effects. Additionally these activities may result in burial of seeds and cysts of plants and animals so they have decreased viability. Plants and animals may be crushed and killed as a result of careless site users. Trampling also may reduce the reproductive output of vernal pool species. Recreational users also may introduce, or facilitate spread of, seeds of invasive plants that could be attached to vehicles, tires, or shoes and clothing. Germination of these seeds may result in competition with vernal pool plants and could further change the vegetative composition of the landscape. Vandals on off-road vehicles have cut down wire fences around vernal pool complexes to gain access to the land. Compaction of soils as a result of unregulated recreational use could reduce germination of seeds.

Loss of pollinator species. A potential threat to vernal pool plants is the decline of essential pollinators due to habitat fragmentation and the loss of upland habitat that supports pollinator species. Habitat loss and degradation interferes with reproduction and dispersal of pollinators. Pollinators for most vernal pool plant species have not been identified, so the status of their habitat cannot be assessed. It is likely that many of these pollinators require the uplands surrounding vernal pools for completion of their life cycle. For insect pollinated plants, the reduction of available habitat for pollinators could decrease pollinator populations, which could reduce reproductive success of the plants. Similarly, many of these pollinators (*e.g.*, andrenid bees) do not disperse great distances (Davis 1998, Leong 1994, Thorp and Leong 1995), so removal or modification of available vernal pool and upland habitat (*e.g.*, through urban development or the accretion of a dense thatch layer preventing access to burrowing sites) could minimize their ability to reproduce and disperse. If pollinators are unable to disperse, or habitat loss causes a reduction in pollinator populations, then it is likely genetic variability and reproductive success of insect pollinated plant species would be reduced, thus affecting the long-term viability of the taxon. Diminished reproductive success could lead to reduced numbers and susceptibility to extinction.

Inappropriate livestock grazing. Livestock grazing has three primary effects on vernal pools: consumption of vegetation, trampling, and nutrient input from urine and feces (Vollmar 2002). Inappropriate management of grazing, from overgrazing, undergrazing, or inappropriately-timed grazing, can result in significant adverse effects to vernal pool ecosystems. Physical trampling by livestock seriously can affect the viability of a species, especially if the species is restricted to a small area or if grazing occurs during sensitive parts of the growing season, such as during periods when the plants bloom or set seed. Research indicates that the perceived need for some amount of ecosystem disturbance should not be interpreted as an invitation to indiscriminately graze vernal pool landscapes. Because vernal pool species exhibit a variety of life history strategies, grazing regimes must take these needs into consideration. Grazing inappropriately for target species may result in problems comparable or greater than those encountered by exclusion of grazing (Vollmar 2002). Without grazing or fire to remove the competition of invasive annuals, the native species may set fewer seed, or add fewer seeds to the seedbanks than were removed through germination or other factors. Additionally, in areas that have been grazed for decades, grazing may be serving a role in controlling populations of nonnative annual plant species and maintaining appropriate inundation periods. Therefore a moderate grazing program (moderate in both stocking rates and length of grazing period) in areas which have been grazed historically, may be preferable to no grazing, especially where burning is impractical. Moderation in grazing lessens the potential to do damage while monitoring information is being gathered and the grazing regime is adapted and improved.

Climate and environmental change. Habitat alteration may result from global climate and environmental changes including nitrogen deposition, increase in atmospheric carbon dioxide, changes in precipitation patterns, and global warming. On a local scale, these changes may result in altering current vernal pool habitat to be more suitable to nonnative species and less suitable for native species. Thus native species could be out-competed resulting in changes to the species' ranges (Dukes and Mooney 1999). Climate and landscape ultimately define a species' range and conditions for growth and survival (Sutherst 2000). Species having larger ranges with individuals in the centers of those ranges will have the greatest chance for survival (Sutherst 2000). The vernal pool regions and core areas in this plan have been selected to include the current known habitat for these species; however, planning for such global changes is complex and beyond the scope of this plan. Should the California and Oregon climate become less hospitable to these species where they currently exist, it may be possible that new areas of suitable habitat would eventually evolve. It is also possible that protecting large blocks of vernal pool habitat, may help moderate the impacts of widespread changes by providing refugia and corridors to new habitat. Future management of preserves may also need to consider management options that respond to new moisture patterns (Peters 1988).

<u>Inappropriate management and monitoring</u>. Although many vernal pool habitats occur within protected areas, inappropriate management and monitoring of these areas poses a considerable threat to the recovery and conservation of vernal pool species and habitats. Examples of inappropriate management include complete elimination of grazing in areas where exotic grasses dominate the uplands and inappropriate timing or intensity of grazing. In addition, inappropriate management actions such as mowing and burning at an inappropriate season may result in deleterious effects to listed species and species of concern discussed in this recovery plan. Management and monitoring plans which do not include an adaptive management approach and do not facilitate natural processes and functions (*e.g.*, appropriate grazing and fire regimes) may not result in positive actions leading to the recovery and conservation of species discussed in this recovery plan. Inappropriate monitoring, although not a direct threat to the species, may limit the ability to determine population trends and recovery needs. Similarly, lack of funding to implement management and monitoring activities may contribute to a decline of habitat conditions and species baseline.

<u>Random, naturally occurring events</u>. Vernal pool plants and crustaceans existing in small habitat patches are vulnerable to random environmental fluctuations or variation (stochasticity) due to annual weather patterns and availability of food and other environmental factors superimposed on cumulative threats to the ecosystem. The populations of many vernal pool species are isolated from other populations and are distributed in discontinuous vernal pool systems. Such populations are vulnerable to stochastic extinction. The breeding of closely related individuals may cause genetic problems in small populations of crustaceans, particularly in the expression of deleterious genes (known as inbreeding depression). Individuals and populations possessing deleterious genetic material are less able to withstand environmental changes, even relatively minor ones.

<u>Overutilization</u>. For some species covered by this recovery plan overutilization represents a threat to their recovery and long-term conservation. Showy or unique species (*e.g.*, delta green ground beetle) are known to be popular with collectors. Although authorized collection of voucher specimens can be regulated, the illegal collection of organisms may surpass sustainable harvest with respect to recruitment.

<u>Disease</u>. Diseases and pathogens specific to vernal pool species are generally unknown. Vernal pool tadpole shrimp are known to be parasitized by flukes (Trematoda) of an undetermined species, which reduce the gonads of both sexes (Ahl 1991). It is likely that other diseases and pathogens are/or could be present in vernal pools. Chytrid fungus (*Batrachochytrium dendrobatidis*) is known to contribute to amphibian declines, and could be spread via infected organisms or contaminated equipment. Diseases and parasitic threats may range from benign to fatal. The vectors and biochemical pathways associated with spread and infection should be considered in order to adequately minimize the threats posed by diseases and pathogens.

<u>Inadequate regulatory mechanisms</u>. Current regulatory mechanisms are in place, however, they are not always fully implemented, enforced, or adequate to protect vernal pool habitats to the point that species addressed in the recovery plan can be fully recovered. The Endangered Species Act is the primary Federal law providing protection for the listed vernal pool species covered in the recovery plan. Since listing, many projects with the potential to destroy, degrade, or fragment vernal pool habitat have undergone consultation pursuant to section 7(a)(2) of the Endangered Species Act. Section 7(a)(2) requires Federal agencies to consult with us prior to authorizing, funding, or carrying out activities that may affect listed species (50 CFR part 402). The Endangered Species Act also provides additional protection for vernal pool species through section 7(a)(1) and section 10(a)(1)(B). Section 7(a)(1) mandates that Federal agencies use their authorities to further the purposes of the Endangered Species Act. Section 10(a)(1)(B) is a mechanism to permit the taking of listed species by persons without a nexus for section 7(a)(2).

Sections 401 and 404 of the Clean Water Act are additional regulatory mechanisms that provide some protection for vernal pool species covered in the recovery plan. Section 401 establishes procedures and requirements to ensure water quality. This section of the Clean Water Act is administered by the State Water Quality Control Board and applicants must have a section 401 permit before they can receive a section 404 permit.

Section 404 permits are issued by the U.S. Army Corps of Engineers. These permits are issued for the discharge of dredged or fill materials into navigable waters of the U.S. Not all vernal pools are subject to the U.S. Army Corps of Engineers; therefore, this regulatory mechanism is inadequate to protect all vernal pool habitat. State and local laws and regulations have not been passed to adequately protect these species. Additionally, inadequate regulatory mechanisms such as the California Environmental Quality Act and other sections of the Clean Water Act have failed to conserve suitable amounts of habitat for vernal pool species. This lost habitat includes the substantial amount of vernal pool habitat being converted for human uses in spite of Federal regulations implemented to protect wetlands. Considering the framework of existing regulatory mechanisms, government agencies must ensure their regulations and policies are being implemented appropriately in order to reduce threats from inconsistent application of regulations and policies.